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AN EXPERIMENTAL INVESTIGATION OF THE INFLUENCE OF THE MOVING PEOPLE ON THE INDOOR RADIO PROPAGATION

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ABSTRACT

Using a new scenario for measurements, the influence of the human traffic on the indoor radio propagation is investigated. This new scenario permits to obtain a signature of moving people all day long. In order to obtain better results for the radio coverage, a new random term must complete the results obtained for power-distance relationship in the absence of moving people.

I. INTRODUCTION

The indoor radio propagation has been an active area of research in recent years, due to the use of radio for indoor data and voice communications within office buildings, convention centers, hospitals, factories and apartment buildings. There have been several studies of the power losses, statistics of the RMS delay spread, polarisation diversity and attempts to model the indoor radio channel. The effects of time variations of the characteristics of the indoor radio propagation caused by human traffic between the transmitter and the receiver have not been thoroughly investigated. Some results are presented in [1-3].

Previous results of the indoor radio propagation [4-5] have been obtained from measurements performed during the night or the week end, in order to avoid the effects of the presence of people. The surrounding environment was kept stationary by preventing movements during the data acquisition. This permits to investigate the influence of the basic building structure (walls, floors and ceilings) and the furniture. The time invariance of the indoor radio channel permits to obtain reproducible and verifiable results.

However, buildings represent a complex environment. Besides the basic building structure, furnishings and people serve as scatterers of radio waves. The presence of the moving people determines variations of the power of the received signal and disturbances of the multipath propagation.

A characteristic of the results presented in this paper is the manner to obtain the movements of the people. For example, in [1] two scenarios are described:

- a) two persons walk briskly around the transmitter and the receiver;
- b) one antenna is rotated by a person around a given location.

In this paper, both antennas are placed in a research laboratory, while the movements represent the natural activity of the researchers, students, visitors, technical and administrative staff during the whole day (24 hours). This allows us to obtain realistic results, reflecting a normal behavior of the moving people.

II. DESCRIPTION OF THE MEASUREMENTS

The measurement system [4] is built up around a HP 8753C network analyzer which generates a swept frequency signal (+20 dBm), from 800 MHz to 1 GHz in 801 equally spaced steps and analyses the received signal. The output of the network analyzer is connected to the transmitting (Tx) antenna through a 50 m coaxial cable with 8 dB attenuation. The calibration is performed at the output of this cable. The signal from the receiving (Rx) antenna is returned through a 4.5 m coaxial cable to the network analyzer to determine the S_{21} parameter. During the measurements, both antennas were kept fixed and placed at the same height: 1.5 m. For each location of the Rx antenna, the magnitude of

S_{21} in dB (representing the power loss) and the impulse response of the channel (computed via an Inverse Fourier Transform) were recorded for further analysis.

The measurements start at midnight and last 24 hours. Each minute a measurement is performed: one minute for the power loss (on the first channel of the network analyzer) and one minute for the impulse response (on the second channel). The data is sent via an IEEE-488 bus to a Tektronix 4041 computer / controller and stored on the hard disk (a 4041 Disk Drive Unit).

The measurements are performed at the ground floor of the LCST laboratory. The Rx antenna is placed in the central room, whereas the Tx antenna is located at one extremity of the laboratory. Therefore, the access to the others rooms imposes the passing near the Rx antenna. The stairs to the first floor are placed between the antennas. Each person going upstairs or downstairs causes a disturbance of the multipath propagation and a small shadowing of the LOS.

III. DATA ANALYSIS

The main objective of these measurements is to determine the modifications of the indoor radio propagation characteristics caused by human traffic. Consequently, the estimation of the radio coverage obtained in [5] in the absence of the moving people can be corrected, in order to obtain realistic results, reflecting a normal behavior of the moving people.

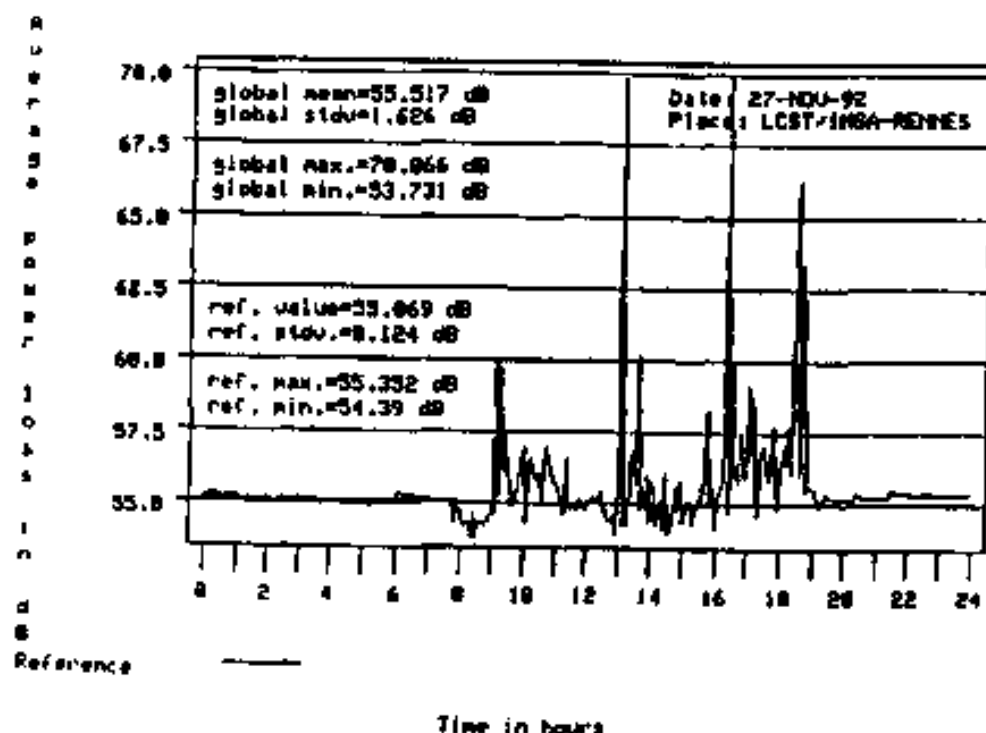


Fig.1. Temporal power loss measurements

Fig.1. shows a first result obtained for the average power loss. During the night (0 - 8 h), the building was deserted. Therefore, the channel can be considered stationary. The power loss is practically constant (55 dB), with a small standard deviation (0.124 dB). This value represents the reference.

During the day, due to the human traffic, the power loss has important variations, from 53.7 dB up to 70 dB. The most values are greater than the reference, so the shadowing is preponderant. However, the smaller values indicate a weak disturbance of the multipath propagation. The greatest values are obtained about 8 h (the arrival of the researchers and the administrative staff), 13 h (lunch time) and 18 h 30 min (the departure of the majority of the researchers). Smaller variations are obtained about 9h 30 min - 10 h and 16 h - 16 h 30 min (coffee breaks). After 20 h the power loss rebecomes practically constant.

Similar results can be obtained for the RMS delay spread, computed from

the impulse response of the channel (fig.2). During the night, the delay spread is practically constant: 21.8 ns, with a small standard deviation (0.38 ns). During the day, one can note variations between 12.3 ns and 33.23 ns.

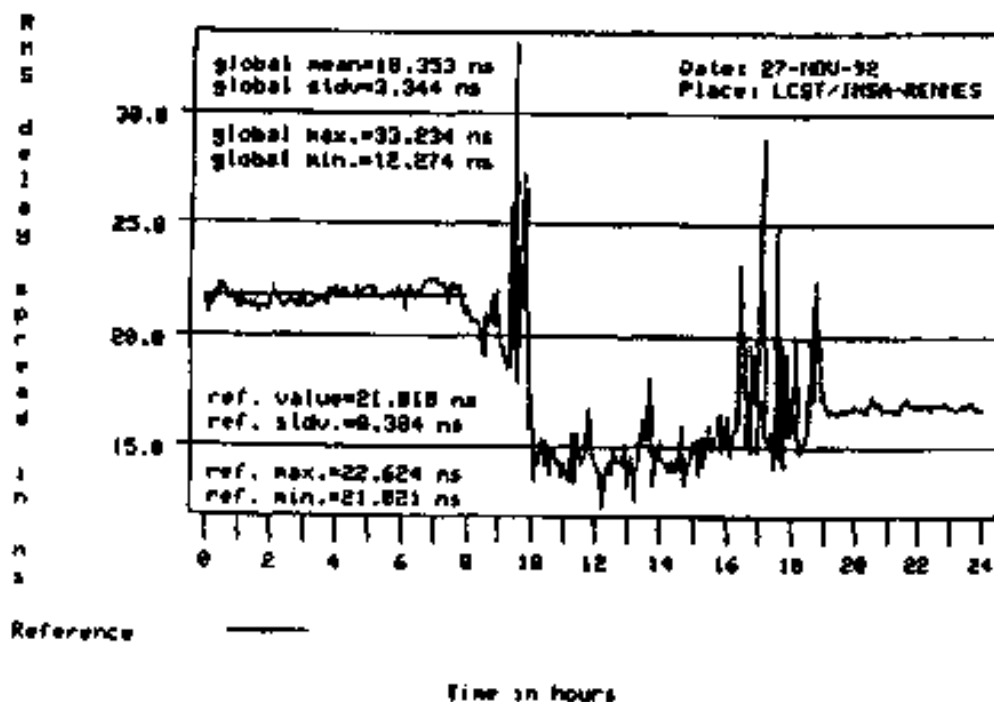


Fig.2. Temporal RMS delay spread measurements

This time, there is a difference between the reference value (0 - 8h) and the final (practically) constant value, about 17 ns. This can be explained by the modifications during the day of the position of several carts made of metal and equipped with pneumatic tires, used for various measurement apparatus. As a general remark for these figures, one can note the strong correlation between the human activity and the obtained results.

For an experimental investigation of the stationarity of the indoor radio channel in the absence of the human traffic, the above results are not sufficient. It is possible to obtain the same average power loss for different frequency responses or the same RMS delay spread for different impulse responses of the indoor radio channel. Therefore, it was necessary to consider the euclidean distance between a reference frequency/impulse response and each response recorded during the day. Practically, the reference response was computed as the average of the first 120 responses recorded during the night (0 - 8h):

$$r = [r(1), r(2), \dots, r(n)] = \frac{1}{120} \sum_{k=1}^{120} [x_k(1), x_k(2), \dots, x_k(n)]$$

Using this reference response, the normalized euclidean distance between a response $x_k = [x_k(1), x_k(2), \dots, x_k(n)]$ can be computed as:

$$d(x_k, r) = \sqrt{\frac{1}{n} \sum_{i=1}^n [x_k(i) - r(i)]^2}, \quad k = \overline{1, 720}$$

Fig.3. shows a plot of the normalized euclidean distance $d(x_k, r)$ for the power loss. One can remark the similarity between this result and the other one shown in Fig.1. Practically, this new parameter can be used as well as the average power loss for the analysis of the influence of the human traffic on the indoor radio channel. Using this new result we can prove the stationarity of this channel in the absence of the moving people. A similar approach was considered for the impulse response of the channel. Using the above results it is possible to obtain a cumulative distribution for the power loss and the RMS delay spread and

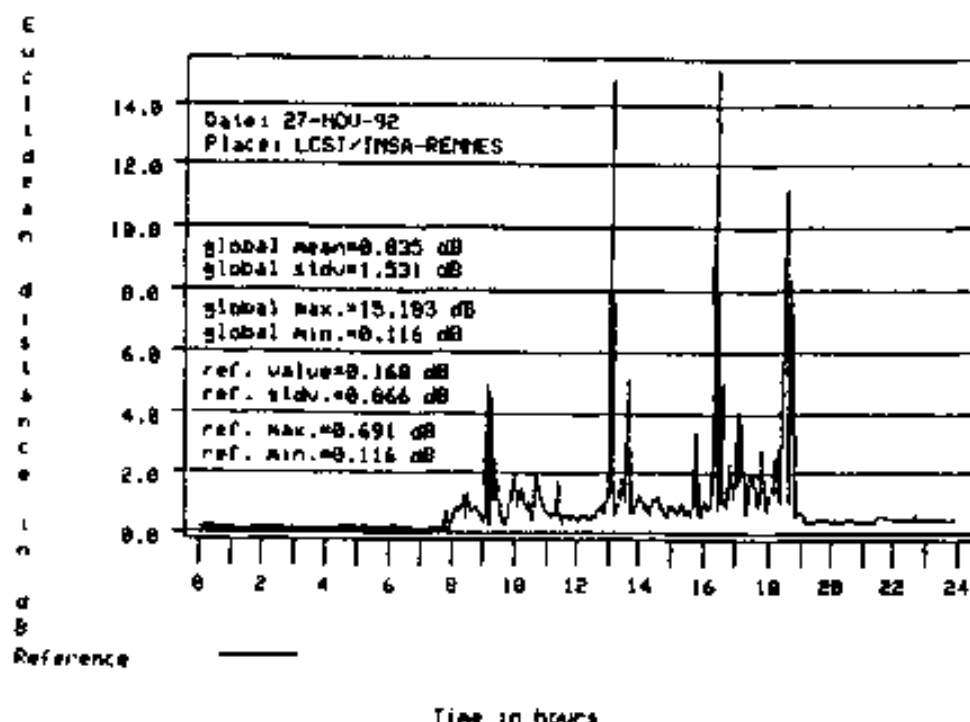


Fig.3. Normalized euclidean distance of the power loss curves versus time

to compare it with a classical distribution as Rician [2-3], Rayleigh [1,3], log-normal and Weibull [1]. Due to the described scenario of these measurements, the obtained results characterize the influence of a natural human traffic on the indoor propagation characteristics.

CONCLUSION

A new scenario for the analysis of the influence of the moving people to the power loss and RMS delay spread has been described in this paper. Using the data obtained from the measurements it is possible to deduce in a simple manner a signature of the human traffic all day long. From the variations of the power loss values it is possible to obtain an improved model for the power - distance relationship with a deterministic term in d^α which describes the long scale variations of the power loss versus distance, a deterministic term which characterizes the small scale variations with the distance of the power loss, a random term which completes the model in the absence of people and a new random term characterizing the influence of the human traffic on the power loss. Using this improved model, it is possible to obtain more realistic estimations of the radio coverage in the buildings.

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